AN

EXPERIMENTAL INQUIRY

INTO THE

ACTION OF ALCOHOL

ON THE

NERVOUS SYSTEM.

BY

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Read to the British Association for the Advancement of Science, at the Meeting held at Aberdeen, in 1859, *and now reprinted from the 'Medical Times and Gazette' for March* 3*d*, 17*th, and* 31*st*, 1860.

LONDON:

PRINTED BY

J. E. ADLARD, BARTHOLOMEW CLOSE.

1860.

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The object of this communication is to establish, by a series of experiments, the mode of action of alcohol on the nervous centres, or rather *the channel* through which alcohol acts on these centres. When a spirituous fluid is taken into the stomach, its influence may be conveyed to the brain, spinal chord, and sympathetic system, by different channels. According to some physiologists, the properties of alcohol are exerted on the nervous centres through the nerves only; others believe that intoxication does not occur unless the poison has come in contact with the brain, by means of the circulation; finally, it is thought by some, that alcohol acts on the nervous centres in both ways. In order to contribute to the solution of this question, I have undertaken the experiments which form the subject of the present paper. I have been ably assisted in these researches by Mr. F. Dupré, Ph. D.

In 1811, a very interesting communication of Sir Benjamin Brodie was published in the '*Philosophical Transactions*'—"On the different modes in which Death is produced

by certain Vegetable Poisons." The distinguished author of this paper expresses an opinion that alcohol acts on the brain through the nerves of the stomach, or, according to his own expression, "In consequence of the sympathy that exists between these organs (stomach and brain) by means of the nerves," this conclusion being derived from the following facts:

1st. That in animals killed by the injection of alcohol into their stomach, he has found this organ to bear the marks of great inflammation but never any preternatural appearance whatever in the brain.

2d. That the effects of spirits taken into the stomach, in one of the experiments, were so instantaneous, that it appeared impossible that absorption could have taken place before they were produced.

3d. That a person who is intoxicated frequently becomes sober suddenly, after vomiting.

4th. That tincture of rhubarb, mixed with the alcohol used in the author's experiments, could never be detected in the urine.

In 1839, Dr. J. Percy published an elaborate and interesting paper, having for its title 'An Experimental Inquiry concerning the presence of Alcohol in the Ventricles of the Brain.' From his researches, Dr. Percy concluded—

1st. That in cases of fatal poisoning by alcohol, although he failed to detect the evident presence of the poison in the fluid effused in the cerebral ventricles, still the substance of the brain yielded alcohol. "Indeed," he observes, "it would almost seem that a kind of affinity existed between the alcohol and the cerebral matter." As a proof of the correctness of this view, the author states that he subjected to analysis for the detection of alcohol a quantity of the blood of an animal poisoned, greater than that which could possibly be present within its cranium, and that notwithstanding, he was able to procure a much larger proportion of alcohol from the brain than from this quantity of blood.

2d. That the rapidity with which alcohol may, under favorable circumstances, be absorbed from the stomach and conveyed to the brain, is remarkable.

3d. That alcohol may be detected in the blood, the urine, the bile, and the liver (of the animals poisoned).

On concluding his dissertation, Dr. Percy observes: "I shall merely endeavour to show that the narcotic effects of alcohol cannot in all cases be satisfactorily explained by adopting exclusively, either the theory of an impression upon the extremities of the nerves, or that of direct action upon the central organs of the nervous system; because, generally, an interval of several minutes elapsed before the slightest manifestation of cerebral derangement was afforded. But, in some cases, the total loss of sensibility and voluntary power so instantaneously followed the introduction of the poison into the stomach, that it cannot be conceived that absorption to a sufficient extent could possibly have taken place . . . . . Little doubt, I think, can be entertained that alcohol may produce its narcotic effects, and even induce a fatal termination, without being absorbed."

Broussais explains the action of alcohol in the same way as Brodie. Trousseau is inclined to adopt the theory of absorption. Dr. Carpenter, although admitting that in some cases death from alcohol may be occasioned by a violent impression on the nerves of the stomach, concludes that this fluid has a peculiar affinity for the nervous centres. This remarkable phenomenon is of importance, being a strong argument in favour of the theory of absorption, and its existence is placed beyond doubt, not only by the experiment of Dr. Percy previously recorded, but also by those of L. Lallemand, Michel Perrin and Duray,[1] who withdrew the blood from the brain in cases of poisoning with alcohol, and succeeded in extracting alcohol from the cerebral substance, thus free from blood.

[1] Thesis, by Leon Thomeuf—'Essai Clinique sur l'Alcoholisme,' Paris, 1859.

It will be observed from these preliminary observations, that the channel through which alcohol acts on the nervous centres is still a matter of opinion, for we possess no positive facts to show us the real *modus operandi* of the poison.

The experiments I have undertaken on the subject may be conveniently divided into three series.

In the first, I investigated the action of alcohol on the healthy animal; choosing the frog on one hand, and the dog on the other.

In the second, I divided the nerves which supplied the parts placed in contact with alcohol, leaving the circulation undisturbed; frogs only were used in this series of experiments.

In the third series, I arrested the circulation of the parts in contact with the alcohol, so that none of the poison could possibly be carried to the nervous centres, and I took care to leave the nervous connections undisturbed between the parts poisoned and the nervous centres. Frogs and dogs were chosen for these experiments.[1]

Series of Experiments, No. I.

Action of Alcohol on Frogs.

Experiment I.—The hind legs of a healthy frog were immersed in alcohol (specific gr. 833[2]) up to the commissure of the thighs. The animal struggled for half a minute, and then remained quiet. One minute and a half after immersion, being removed from the alcohol, it jumped about. The hind legs of the frog were replaced in the alcohol two minutes and a half after the beginning of the experiment. Five minutes and a half after it had first been immersed, the frog was again placed on the table, when it moved its body slightly, but the posterior extremities were powerless. One minute

[1] These experiments were undertaken in the months of May, June, and July, 1859, when frogs were easily procured, and in a very lively condition.

[2] This was the specific gravity of the alcohol used in my experiments.

and a half later, the frog's hind legs were again immersed in alcohol. Eight minutes after the beginning of the experiment, respiration stopped, the sensibility of the eyes was very slight and hardly perceptible. On pinching its fore legs or body, the animal remained motionless, but now and then gasped. Thirteen minutes after the frog had first been immersed, no gasping or breathing could be brought on by pinching the skin; eyes quite insensible. No shock had taken place. The thorax of the frog was now opened, and the heart found beating.

Experiment II.—The hind legs of a large frog were immersed in alcohol. Two minutes and forty-five seconds after immersion, the animal was completely insensible, but continued breathing, showing the occurrence of a shock. Nine minutes after immersion breathing ceased. One minute afterwards, on being taken out of the alcohol, the animal moved slightly its head and anterior extremities, and then remained motionless; pinching the frog brought on no muscular contractions. Three minutes later the thorax was opened, and the heart found beating.

Experiment III.—The hind legs of a large frog were immersed in alcohol, as in the preceding experiments; it struggled a great deal at first, for three quarters of a minute. Then followed a state of perfect insensibility, or shock, when no muscular contractions could be brought on by pinching the animal's body; this condition lasted for two minutes. Sensibility then returned, and the animal moved its body and arms readily when pinched, but its legs had become immovable. Four minutes after the beginning of the experiment, the frog was again insensible. I may here observe, that during these periods of transient insensibility, or *shock*, the respiration continued, and the eyelids usually moved on touching the eyeballs. Two minutes later, or six minutes after the animal had first been immersed, it was removed from the alcohol, where in all probability it would not have recovered from the shock.

Conclusion.—These experiments show:

1st. That when the legs of a frog are immersed in alcohol, as far up as the commissure of the thighs, the animal ceases breathing and loses its sensibility in a period varying from ten to thirteen minutes.[1]

2d. That the limbs in contact with the alcohol become insensible and powerless sooner than the other parts of the animal.

3d. That frequently a shock occurs shortly after the immersion, consisting of the cessation of the power of motion, although respiration continues, and the eyelids usually remain sensible, or move on irritating the eyeball.

4th. That the shock, which occurs shortly after the immersion, may continue until the animal dies, there being little or no return of spontaneous or excitable muscular action.

5th. That the shock may disappear shortly after its occurrence, and return again afterwards.

Action of Alcohol on a Dog.—Although the effects of alcohol on dogs have been closely investigated by Brodie, Percy, and others, I beg to report the following experiment, which will be found interesting mainly in its connection with others to be subsequently related.

Experiment IV.—The dog had been fed at about 10 a.m.; the experiment was undertaken the same day at 1·31 p.m. Previous to any alcohol being injected into the animal's stomach:

Respiration . . .	20 per minute.
Pulsations of heart . .	120 „

One ounce of alcohol, diluted with as much water, was now injected into the dog's stomach by means of a syringe and canula. Two minutes after the injection was completed, the animal began tottering.

[1] In another similar experiment which will be subsequently reported, the functions of sensation and respiration were arrested after an immersion of nine minutes.

Respiration varies from 38 to 44 per minute.

Pulsations of heart, 132 per minute.

Twelve minutes after the injection, can hardly stand, and tumbles about.

Sixteen minutes after the first injection, I again introduced into the dog's stomach one ounce of alcohol diluted with one ounce of water. One minute and a half later, lies down and makes useless efforts to rise. Fifteen minutes after the second injection:

Respiration . . .	40 per minute.
Pulsations of heart . .	176 „

Twenty minutes after the second injection:

Respiration . . .	32 in one minute.
Pulsations of heart . .	160 „

Forty minutes after the last injection, the dog appears to be sinking; cannot be roused when shaken; the eyelids are nearly immovable when the eyeballs are irritated. Fifty minutes after this last injection:

Respiration . . .	33 per minute.
Pulsations of heart . .	132 „

Evinces no pain when tongue or nose are strongly pinched, but still moves the eyelids when eyeballs are touched. Seven minutes later respiratory motions are exceedingly slight, mostly abdominal, and respiratory murmur very faintly heard.

Respiration . . .	16 per minute.
Pulsations of heart . .	132 „

Eighty-three minutes after the second injection, respiration becoming more thoracic, and respiratory murmur now more distinctly heard.

Eighty-eight minutes after the second injection, one ounce of alcohol, diluted with an equal bulk of water, was again thrown into the dog's stomach. Six minutes later, when the eyeballs are touched, the eyelids remain perfectly motionless.

Respiration . . . 28 per minute.
Pulsations of heart . . 47 „
(Weak and very irregular.)

Convulsive motions in the nostrils just previous to each inspiration; insensibility complete. Fifteen minutes after the third injection, the respiration suddenly ceased, the pupils dilated to a remarkable extent, and then again began contracting. About one minute and a half after respiration had stopped, the dog took an inspiration, which was followed by others at the rate of eight in one minute; the heart could then be heard beating twice at the end of each inspiration, and then remained quiet until the next inspiration took place. Twenty-eight minutes after the third injection, the dog ceased breathing for two minutes and a half, during which time the heart was heard beating regularly, and the pupils dilated. Respiration now returned. Five minutes and a half after the animal had again commenced breathing, it was observed to take deep inspirations; the respiration had become stertorous; pupils contracted. Fourteen minutes after respiration had returned, heart pulsates seventy-eight times in one minute; is irregular. The dog now ceased breathing for half a minute. Fifty minutes after the last injection, respiration stopped, and the pulsations of the heart could no longer be perceived.[1] Three minutes afterwards, the animal took two inspirations; the pupils were dilated. Sixteen minutes later, there had been no return of respiration; the dog was dead.

This experiment shows that alcohol acts first on the brain, producing a cessation of voluntary motion, and later on the medulla oblongata and spinal chord, arresting the respiration; in addition to which, it may be concluded from the observations on frogs, that the pulsations of the heart persisting after the cessation of the sensibility and respiration, the sympathetic system is the last to be affected.

[1] Probably, however, the heart continued beating until respiration ceased; when very faint, it is questionable whether the pulsations of the heart may be detected by auscultation.

Series of Experiments, No. II.

In the following experiments the circulation was left undisturbed, but the nervous connections between the parts in contact with the alcohol and the nervous centres were severed. Frogs only were used. After having incised the skin along the inferior part of the spine, and lifted with the forceps the coxigeal extremity of the vertebral column, I carefully cut through its muscular adhesions, and then removed it. On the right and left of the middle line, the crural nerves could be detected proceeding from the spinal chord to both inferior extremities; these nerves were taken up with the forceps, and divided. Thus, there remained no other connection between the legs of the animal and the nervous centres, but by means of the circulation. In every case the frog was allowed to recover from the shock of the operation, which took a few seconds, before proceeding with the experiment.

It is evident that, supposing in this case, after the immersion of the frog's legs in alcohol, sensation and respiration ceased as quickly as when healthy frogs were submitted to experiment, we must conclude that the nervous connections existing between the legs of the frog and the nervous centres of the animal were not possessed of the power of transmitting the action of the poison to these organs; but if, on the contrary, it be shown that the operated frog, having its inferior extremities immersed in alcohol, preserved its sensation and respiration for a longer period than a healthy frog placed under the same circumstances, then we are compelled to admit that the impression of the alcohol on the nervous centres is transmitted to those centres, at least *partly*, by the nervous tracts.

Experiment V.— A very large frog was operated on as described above (slight bleeding occurred during the operation), and its legs were immersed in alcohol. At first, no muscular contractions took place; thirty seconds after immersion, the

frog struggled a little. It was quite sensible, and continued breathing, in which condition the animal remained until twenty-two minutes after immersion, when its sensibility began to diminish; one minute later, the frog was insensible, and respiration stopped.

Experiment VI.—The operation was repeated on another frog. A very slight hæmorrhage took place from some muscular capillaries. No struggling occurred until two minutes after immersion, when it moved violently of its own accord. No shock had taken place; sensation had remained unimpaired during the whole time of the experiment. The frog continued in the same condition, with occasional struggles, until eighteen minutes after immersion, when it suddenly became insensible, and respiration ceased.

Experiment VII.—Two middle-sized frogs were submitted to the same operation, their crural nerves being cut without any hæmorrhage occurring. Another healthy frog was then chosen, and the legs of the three animals were immersed in alcohol at the same time.

First Frog (operated).—Sensation and respiration unimpaired until six minutes after immersion, when sensation began to diminish. Fourteen minutes after immersion, the animal is becoming insensible. Fifteen minutes after immersion, insensibility complete, respiration has just ceased.

Second Frog (operated).—Moved its fore legs very little when the hind legs were immersed; sensation and respiration continued unimpaired till six minutes after immersion, when the frog felt a little less on being pinched. Was still in the same condition eight minutes after immersion, when it had a fit of convulsions, but the sensation and respiration continued. Twelve minutes after immersion, the frog is much less sensible, and breathes irregularly. Fifteen minutes after immersion, insensibility nearly complete;[1] respiration has ceased for the last minute.

[1] Sensation disappeared completely a few seconds latter.

Third Frog (not operated).—When first immersed, struggles a great deal, and there is some difficulty in keeping its legs in the alcohol. Three minutes after immersion, the animal, when pinched in its body or fore legs, is observed to be less sensible than the two other frogs at the same period. Five minutes after immersion, is much less sensible than the two others at a similar period. Six minutes after immersion, is nearly insensible, the frog continuing breathing the whole time. Eight minutes after immersion, is become quite insensible; nine minutes after immersion, respiration stops. The following are the conclusions which result from this second series of experiments:

1st. On the operated frogs, or those in which no action could be exerted by the alcohol on the nervous centres, through the nerves, a shock never took place.

2d. The time that elapsed from the immersion (in alcohol) of the legs of the operated frogs, until the occurrence of insensibility and the cessation of respiration, varied from fifteen to twenty-three minutes. I may here observe, that a healthy frog, having its legs in alcohol, was deprived of sensation and ceased breathing in from ten to thirteen minutes; thus showing that the circulation is the principal channel of transmission of the action of alcohol from the periphery to the nervous centres, and also that the nerves have decidedly a slight influence in conveying the influence of the poison to these centres.

Series of Experiments, No. III.

Having hitherto inquired into the action of alcohol on the nervous centres, through the medium of the circulation and nerves, and also through the medium of the circulation only, it was next of importance to investigate the influence of this poison on the nervous centres when transmitted exclusively through the nerves. For this purpose, frogs and dogs were operated in such a way as to interrupt completely the circulation between the parts placed in contact with the alcohol

and the nervous centres, leaving the nervous connections undisturbed. The sacrum and part of the vertebral column of frogs were removed as high up as the bifurcation of the abdominal aorta, the operation being performed according to the process adopted in my former experiments, and previously used by C. Bernard, in his researches on the action of poisons. The aorta was then tied above its bifurcation, and finally a ligature was introduced between the body of the frog and the crural nerves, by which means the body was tightly tied, leaving the nerves quite free. I began by ascertaining how long a frog could live after having been thus operated on, and with this end in view the following experiment was undertaken.

Experiment VIII.—The abdominal aorta and the body of a frog were secured in separate ligatures, leaving the crural nerves quite free; the operation was performed at 5·50 p.m. The frog was then placed in a capsule containing a little water, some fresh grass was put upon the animal, and the whole was covered with a large glass jar. The evening of the next day, at 5·30 p.m., the animal was quite alive. On the following morning, at 10·30, it was dead. The frog had consequently survived the operation for a longer period than twenty-three hours and forty minutes.

Experiment IX.—At 10·36 a.m. a frog was operated upon as in the last experiment. Immediately after the operation it jumped about, thus showing that the irritability of the crural nerves was still perfect, although the supply of blood to the posterior extremities had been entirely cut off. The hind legs were then immersed in alcohol; the animal immediately began struggling to remove them from the fluid; about fifteen seconds later, it ceased moving. When its fore legs or body were pinched, it now remained perfectly motionless; on irritating the eyeball, however, the eyelids were observed to be still sensible, and respiration continued. This was the evident sign of a shock, from which the animal began to recover two minutes after immersion; three

minutes and a half after immersion, strong muscular contractions were excited in the body and fore legs by pinching the frog; its hind legs moved but very slightly. Seven minutes after immersion, body and fore legs very sensible; but hind legs remain motionless. The animal was then secured to a filtering stand, with its legs dipping in alcohol; its body was covered with a little wet grass, and the stand was placed in a capsule containing a little water; finally, the whole was enclosed under a glass shade. On that day, at 2·40, the frog was observed to breathe at wide intervals, and move only slightly when pinched; respiration and sensation then ceased; it had lived for four hours and four minutes.

It will be observed that, in other experiments of the same kind, the frogs lived longer than on the present occasion; this may be accounted for by assuming, that the violent shock which occurred in this experiment diminished the animal's vitality.

Experiment X.—The same operation as above was performed on a frog at 2 p.m.; it hopped about immediately after, and its hind legs were at once immersed in alcohol. Nine minutes later the hind legs were immovable, but the sensibility of the frog's body and anterior extremities remained unimpaired. There had been no shock. The animal was now secured to a stand, as in the previous experiment, and left undisturbed. At 5·50 p.m. it was quite alive; the next morning, at 8·45 a.m., the frog was found dead; it must therefore have lived longer than three hours and fifty minutes, and less than eighteen hours and forty-five minutes.

Experiment XI.—Two frogs of about the same size were next submitted to experiment; one of them had its aorta and body tied, leaving the crural nerves free; the aorta only of the other was secured. These operations were performed at 4·40 p.m., and the posterior extremities of both frogs were immersed in alcohol. In order to make sure that the wound could not possibly come in contact with the alcohol, a string was passed loosely under the frogs' abdomens,

and fastened to a ring fixed above to the stand. Both frogs were perfectly alive at 5·30 p.m. The next morning, at 10·20, the frog whose body and aorta had been tied was still alive, respiration had apparently ceased, but could be excited by irritating the skin; on touching the eyeball the eyelids moved; when the toes of the fore legs were pinched, slight but decided movements were induced in the whole body above the ligature; respiration and sensation continued but for a few minutes later. On opening the animal's thorax, its heart was found beating regularly, at the rate of fifty-one pulsations per minute, and went on pulsating for three hours. Consequently, this frog lived for a little longer than seventeen hours and forty minutes from the beginning of the experiment. The other frog, whose aorta only had been tied, was found quite dead the day after the operation; on opening the thorax, the heart was observed to have ceased beating.

In another experiment with two frogs, where the aorta only was tied, the animals lived, with their posterior extremities immersed in alcohol, longer than six hours and five minutes, and less than twenty-three hours and five minutes.

These experiments agree with those of the second series, in showing that alcohol acts *principally* on the nervous centres through the circulation, but *partly* also through the nerves; for a healthy frog, with its posterior extremities immersed in alcohol, will cease breathing and feeling after a lapse of time varying from ten to thirteen minutes, while a frog having its crural nerves divided, and its circulation left undisturbed, will cease feeling and breathing from fifteen to twenty-three minutes after its legs have been immersed in alcohol. Moreover, a frog in which the circulation of the parts in contact with alcohol is arrested, although the nerves of these same parts are left undisturbed, will feel and breathe for from four to eighteen hours after the operation. But although sensation and respiration may thus continue for

from four to eighteen hours, when the poison can act on the nervous centres only through the nerves, yet these functions would both last still longer if, under the same circumstances, the frog's hind legs were not immersed in alcohol, as is seen by Experiment VIII; on which occasion the frog survived the operation longer than twenty-three hours and forty minutes. Consequently we may infer that the alcohol deprived the frog of sensation and respiration exclusively by its action through the nerves at least five hours sooner than would have happened merely from the effects of the operation.

From the foregoing experiments we may also conclude that when alcohol produces a shock, the phenomenon is due to the action of the poison transmitted to the brain by the nerves.

Experiments on Dogs.

The following experiments confirm the results obtained from my researches on the action of alcohol upon frogs, from whence it may be safely concluded, that with the human body the influence of alcohol on the nervous centres is exerted principally through the circulation, but also to some extent through the nervous tracts. In order to prevent any absorption from taking place at the stomach, I placed a ligature on the thoracic aorta of several dogs, and then, having injected alcohol into the animals' stomachs, the result of the experiment was carefully noted. The following process was adopted for tying the aorta within the thorax: an incision was carried through the skin between the fifth and sixth rib, close to the vertebral column, and a small aperture was made into the cavity of the thorax; through this aperture I inserted an aneurism-needle, invented by Mr. Trant of Dublin, for tying deep-seated arteries, and so constructed that the thread is drawn from the needle by means of a hook working in the handle of the instrument; the extremity of the curved needle was moved gently across the bodies of the

vertebræ, so as to come in contact with the aorta, and then, on turning round the instrument, the vessel became included within the concavity of the needle. The hook being now pushed forward from the outside, caught hold of the thread in the eye of the needle, and then the thread was withdrawn. I found it occasionally difficult to bring the needle into contact with the artery, but this difficulty was overcome by introducing my little finger into the thorax, and feeling for the vessel.

Experiment XII.—This experiment was undertaken for the purpose of determining how long a dog could live after its thoracic aorta had been tied.

At 10 o'clock a.m. I secured, in a ligature, the aorta of a nearly full-grown young dog; the operation was performed with some difficulty, and attended with a certain amount of hæmorrhage. Immediate paralysis of the muscles of the posterior part of the body, beyond the ligature, occurred. The operation being over, the animal appeared much weakened, and laid down; but the hind part of its body being held up, it walked about the laboratory on its front paws. A quarter of an hour after having been removed from the operating table, the dog rose of himself on his front legs and walked, dragging after him his hind legs, which were perfectly powerless. At 11·5 o'clock, it became restless, but still crawled about the room, although with great difficulty, balancing its body on the hind quarters. At 11·50, it laid down on the floor, howling and struggling. At 11·55, can no longer get up on its fore legs. At 12·15, lays down, shutting its eyes partly, but opening them when called. At 12·45, remains quite quiet, sensibility continues; 12·50, when the hind legs are supported, is unable to stand on its fore legs. From 12 o'clock has become seized with convulsive motions, which have continued increasing, the dog remaining quite sensible; 1·58, the convulsions have diminished; eyes now insensible; 2·15, eyes quite insensible, pupils dilated; breathing ceases; the animal is dead. It had, therefore, lived for four hours and fifteen minutes after the operation.

Experiment XIII.—At 3·27 o'clock, I tied the thoracic aorta of a dog; complete loss of mobility in the posterior part of the body ensued; the pulsations of the heart were heard as a low, indistinct murmur. Half an ounce of alcohol, diluted with the same quantity of water, was injected into the dog's stomach; immediately afterwards it struggled to rise, but was unable to support its body on its fore legs; no other effect was produced. Ten minutes later, a second similar dose of alcohol was injected into the animal's stomach. Three minutes afterwards it began howling; when the hind legs are supported, it walks about steadily on its front paws. Ten minutes after this last injection, vomited a small quantity of fluid. Two minutes later, the dog was made to take one ounce of alcohol, diluted with an ounce of water, which was followed, one minute afterwards, by the ejection of about one ounce of the same mixture. When the hind legs are supported, the animal now runs about steadily on its fore legs. Ten minutes after the last injection, seven eighths of an ounce of alcohol, of the same strength as previously, was injected into the dog's stomach; no visible effect was produced. Fifteen minutes later, the dog has decidedly become weaker. At 3·55, I again injected into its stomach one ounce of alcohol, diluted with an equal bulk of water, by which, however, the animal appeared unaffected, but its weakness was gradually increasing. At 4·8, one ounce of alcohol, diluted as above, was again thrown into the dog's stomach; ten minutes later, it could no longer stand on its fore legs when the posterior extremities were supported. At 4·25, another similar dose of diluted alcohol was injected. Five minutes later, great weakness, and apparent insensibility when the animal's nose is pinched; eyes quite sensible. At 4·42, and at 5, the injection into the dog's stomach of an ounce of alcohol, diluted with as much water, was repeated. At 5, while engaged with the last injection, the dog died.

This dog had lived, consequently, two hours and twenty-seven minutes after the operation, and during that time had been made to take seven ounces and a half of alcohol, diluted

with an equal bulk of water,[1] without having exhibited signs of alcoholic intoxication, and the animal had remained sensible to the last. A post-mortem examination showed that the aorta had been perfectly tied.

From this experiment we may conclude that the poisonous effect of alcohol, known under the name of alcoholic intoxication, is not produced when the alcohol cannot reach the nervous centres; but that, nevertheless, the contact of this poison with the nerves of the stomach hastens death. The dog used in the last experiment lived only two hours and twenty-seven minutes after having been operated upon, while it may be remembered that another dog, whose aorta was tied, but to which no alcohol was given, lived four hours and fifteen minutes after the operation.

As it might be objected that in the last experiment the irritability of the nerves of the stomach had been destroyed before the animal had taken a sufficient quantity of alcohol to produce an effect on the nervous system, I undertook the following experiment.

Experiment XIV.—A mixture was prepared, consisting of seven ounces of alcohol and five ounces of water. At 2·58 o'clock, I tied the thoracic aorta of a dog;[2] this was followed by complete paralysis of the hind legs. Not later than three minutes after the operation, the whole of the twelve ounces of alcoholic liquid were injected into the animal's stomach, by means of a stomach-pump; immediately afterwards, about two ounces of fluid were vomited. Six minutes after the injection, one ounce and a half of alcohol, diluted with one ounce of water, were again introduced into the dog's stomach. Not the slightest symptom of drunkenness occurred immediately after the first injection, or three or four minutes later. Ten minutes after the first injection, two ounces of fluid were again vomited. At 3·15, the dog was observed to become rather weaker, but when the hind

[1] About one ounce of diluted alcohol had subsequently been vomited.
[2] While the aorta was being tied, the ligature broke.

legs were supported, it still walked about without tottering. At 3·18, again vomited two ounces of fluid. At 3·20, slight motion of the hind legs. At 3·28, can no longer stand on its fore paws when the hind legs are supported. At 3·30, can stand a little on its hind legs when leaning against the wall; when the posterior extremities are held up, walks about tottering, and falls; symptoms of drunkenness are now evident. At 3·32, vomits a mixture of bile and alcoholic fluid; 3·35, can no longer stand on its fore paws when the hind legs are held up; 3·40, is nearly comatose; eyes still sensible. Two minutes later, respiration ceased for a whole minute; eyes now perfectly insensible; 3·54, sensibility of the eyes returning; heart felt beating quite distinctly 118 times in a minute; 4·12, heart's action no longer perceived; pupils dilated, complete insensibility of the eyes. The heart could be felt beating irregularly for two minutes and a half after respiration had stopped.

At the post-mortem examination, an hour after death, a quantity of fat and cellular tissue was found included in the ligature of the aorta. I observed the thread to be loosely tied on the vessel; and by exerting a slight degree of traction the ligature came undone.

The preceding experiment is exceedingly interesting, as it shows:

1st. That when the circulation of the stomach in a dog is arrested, the sudden injection into this organ, immediately after the operation, of about fourteen times as much alcohol as would be necessary to make the animal intoxicated under ordinary circumstances, causes no symptom of poisoning beyond vomiting; not the slightest evidence of alcoholic intoxication occurs.

2d. That as soon as the circulation is re-established, and alcohol becomes absorbed from the stomach into the circulation, symptoms of alcoholic intoxication occur, and finally death ensues from the effects of the poison.

In conclusion, the principal results to be drawn from the experiments related in this paper are as follows:

1st. That alcohol acts *principally*, though not *exclusively*, on the nervous centres by means of absorption, and consequently through the circulation.

2d. That alcohol exerts a *slight* but *decided* action on the nervous centres through the nerves, independently of the circulation.

3d. That the action transmitted through the nerves may be of two kinds:

(*a*). It may give rise to a shock, or temporary complete suspension of sensibility and mobility (with the exception, perhaps, of that of the eyelids), although respiration continues.

(*b*). It may produce no other visible effect than hastening death.

36, Chapel Street, Belgrave Square,
London.

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